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Fly Ashes for HVFAC Production

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Abstract

Development and application HVFAC in the Czech Republic is no easy task. For production HVFAC are important raw materials. especially the quality and characteristics of the ash, which is used for the production HVFAC. The article compares selected chemical and physical properties of Czech fly ashes by foreign fly ash.

Keywords: fly ash; HVFAC; chemical properties; physical properties;

1. Introduction

In article are compared chemical-physical properties of fly ashes with foreign fly ashes. It is mainly studied the chemical composition of fly ashes by classical chemical analysis and XRF analysis, and grain fly ashes (dry sieving through a sieve 0.063 and 0.045. the determination of particle size distribution fly ashes on the laser granulometer or specific surface area according to Blaine).

Nomenclature

HVFAC= High Volume Fly Ash Concrete, concrete with a high content of fly ash used Malhotra in late eighties of the XX century. This concrete has a low water cement ratio and min 50% replacement of cement with fly ash to

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semi according to ASTM Class F. The low water cement ratio and the use of chemical additives developed specifically for HVFAC is the workability of concrete slump cone at the level of 150-200 mm.

2. The tested fly ashes

The aim of the research is to select the most suitable fly ash for the development HVFAC from domestic raw materials. For the tests were selected following commonly used ashes in concrete in the Czech Republic:

- brown coal fly ash from the power plant Ledvice (marked L)
- brown coal fly ash from the power plant Chvaletice (marked C)
- brown coal fly ash from the power plant Melnik (marked M)
- brown coal fly ash from the power plant Opatovice (marked O)
- coal ash from power plants Detmarovice (marked D)

As the reference fly ash was selected coal fly ash Durra Pozz of power Lethabo. South Africa (marked J).

This fly ash is characterized by uniform quality, high fineness declared and ranks among the top quality fly ash in South Africa. Quite commonly it used in concrete as a cement replacement in quantities often exceeding 30 wt% [3]. Comparison of Czech fly ashes with the reference fly ash was carried out in order to assess the quality of Czech fly ash in the world. The aim of the research is to identify what deficiencies Czech fly ashes by composition have.

Altogether was studied 6 different fly ashes and two selected cements identified as CEM A (CEM I 42.5 R) and CEM B (CEM II / A-LL 42.5 R).

3. The chemical and physical properties of selected fly ashes

3.1. Chemical composition of fly ashes

Results of classical chemical analyzes are presented in Table 1. Values of classical chemical analysis differ from the value derived from XRF analysis in the case of minor compounds. at least in the case of the majority of the compounds, there are differences in the range of 1-3%, but this is the difference of the same character. ie the content of CaO and SiO_2 is always higher. Fe_2O_3. TiO_2 were always lower. and Al_2O_3 content is comparable to or lower in classical chemical analysis than in the XRF-analysis.

Czech fly ashes are, according to the classification given in [1], between the low-potassium fly ash (class F according to ASTM 6618). As shown by the data in Table 1, there are not extreme differences in the content of the specified oxides. The only exception is Chvaletice fly ash, which is characterized by a high content of Fe_2O_3. All the fly ashes have a very low loss of annealing. Loss of annealing shows the proportion of organic carbon. The higher the organic carbon content, the higher the fly ash water needs and the harder the concrete made with the ash aerated. Therefore, it is required that the size of the ignition loss of good quality fly ash was minimized.

The reactivity of fly ash can also be assessed using quantitative XRD analysis using internal standard evaluation by the Rietveld method. Although reactive vitreous phase is X ray amorphous, is in this way possible to check the contents of other non-reactive or very little reactive phase (mullite. maghemite. hematite. crystalline silica. anhydrite) and thus indirectly evaluate the reactivity of the tested ashes.

For the evaluation of the content of pozzolanic phases was derived in the reference [2] the pozzolanic potential index (PPI = Pozzolanic Potential Index). This index assesses the ability to participate in the fly ash pozzolanic reaction leading to an increase in long-term strength. Derivation of the PPI is based on the fact that clay impurities contained in the coal combustion have different proportions of illite and kaolinite. While the combustion of coal kaolinite changes to mullite. illite becomes to glass phase (pozzolan) due to the content of K_2O. Molar ratio K_2O and

Al_2O_3 reflects the relative ratio between illite and kaolinite, and is directly proportional to the glass phase content in the ash. It is calculated from the formula:

$$PPI = 10 \cdot \frac{content\ K_2O}{content\ Al_2O_3} \tag{1}$$

Authors work [2] separated based on the size of PPI fly ashes into three classes:

- Class 1 – fly ashes with high PPI > 1.0
- Class 2 – fly ashes with medium 0.5 < PPI > 1.0
- Class 3 – fly ashes with low PPI < 0.5

PPI is given in Table 1. The highest value of PPI has Detmarovice ash (class 1). the lowest ash Dura-Pozza (Class 3), of the Czech ashes the worst PPI has ash Ledvice.

Table 1. Chemical composition of fly ashes and cements, specific surface area, density, humidity and PPI

	Fly Ash						Cement	
Composition [%]	L	M	C	O	D	J	CEM A	CEM B
Loss of ignition	0.59	0.84	1.11	0.68	1.78	1.84	5.52	3.24
CaO	4.21	2.5	4.77	2	5.61	3.2	61.3	63.4
SiO_2	52.8	55.1	50.3	57.7	55	54.4	18.2	19.61
Al_2O_3	31.9	31.5	25.8	29.5	24.7	33.1	6.15	4.68
Fe_2O_3	4.72	4.76	13.17	4.26	5.63	4.1	3.09	2.67
K_2O	1.19	1.65	1.21	2.09	2.76	0.7	1.04	0.76
$Na_2O_{ekv.}$	0.32	0.29	0.46	0.31	0.65	0.29	0.13	0.14
$CaO_{free.}$	0.11	< 0.1	0.11	< 0.1	0.1	0.17	-	-
SO_3	0.4	0.2	0.6	0.2	0.2	0.15	2.63	2.35
SiO_2+Al_2O_3+Fe_2O_3	89.42	91.36	89.27	91.46	85.33	89.17	27.4	26.96
Specific surface area [m^2/kg]	230	191	225	213	285	367	420	333
Density [kg/m^3]	1930	1850	1930	2015	2300	2380	3090	3080
Humidity [%]	0.26	0.28	0.32	0.23	0.27	0.24	-	-
PPI	0.37	0.52	0.47	0.71	1.12	0.21	-	-

3.2. Granularity of fly ashes

The granularity of fly ashes, assessed as the residue on sieve of 0.045 mm is tested according to EN 451-2 wet sieving. According to residue on the sieve 0.045 mm in the standard EN 450-1, the fly ashes were classified by two categories:

- Category N - maximum residue on sieve 40 %
- Category S - maximum residue on sieve 12%.

Screening was performed for dry sieving time was 60 minutes; the test sieve was fitted lid to release fine particles. For each fly ash was two times determined the average assessed value of a measurement error. The residue on sieve was determined as the residue on sieve of 0.045 mm and also residue on sieve of 0.063 mm (Fig. 1).

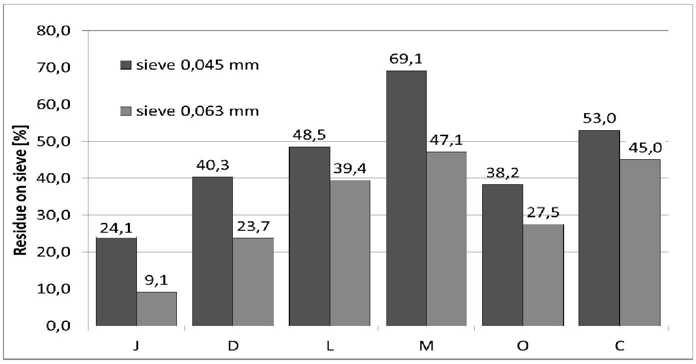

Fig. 1. Determination of fineness of fly ashes - the residue on sieve 0.045 mm and 0.063 mm - screening for droughts

Although we selected test procedure different from the standard procedure, it is safe to say that all the tested ash Czech satisfy only category N and ash Dura-Pozzo is much finer than the Czech ashes.

In Table 1, below are presented the results of the fly ashes specific surface area according to Blaine (EN 196-6). The values of specific surface of cement are taken from statistics of quality published by the cement manufacturers.

In Table 2, are selected sub-frequency representations of the ash particles respectively cement, which were obtained by measuring the laser granulometer and evaluated here mean particle size (D50). Graphical evaluation of granularity is shown in Fig. 2. Grain size analysis of laser granulometer shows that South African fly ash has a particle size similar to the tested cements. Czech ashes are much coarser and how big the difference is, is very visible on the mean particle size D50 (Table 2).

From the evaluation of all the performed granulometric analyses it is shown that the Czech ashes are significant by different. Nevertheless, we can distinguish two groups among Czech grain ash. The least is fine Melnik ash and together with fly ash Chvaletice it forms a group of low fly ashes fineness. Fly ash Detmarovice and Opatovice are one of the finest Czech ashes. Between the two groups is Ledvice ash. Opatovice ash is characterized by having a large representation of small particles (below 20 microns) and large particles (above 100 microns).

For this reason, the equivalent surface area oh Ledvice ash, although the results of balances on residue on sieve are similar to grain Detmarovice ash. Based on these results, we evaluate Detmarovice ash as the finest Czech ash.

Table 2. Particle size in microns which are represented at a frequency of 10. 50 (average particle size) and 90% by volume

	Fly ash						Cement	
frequency	L	M	O	C	D	J	CEM A	CEM B
%	µm	µm	µm	µm	µm	µm	µm	µm
D10	22.5	***23.3***	17.2	23.1	16.8	**2.8**	2.5	3.7
D50 (median)	***54.6***	53.5	47.7	50.2	48.4	**14.7**	13.3	18.0
D90	105.9	109.9	***122.6***	102.2	104.8	**43.4**	36.3	43.4

Note: ***Italics*** indicate the largest size particles and the **underline** indicates the smallest particle size for a given frequency

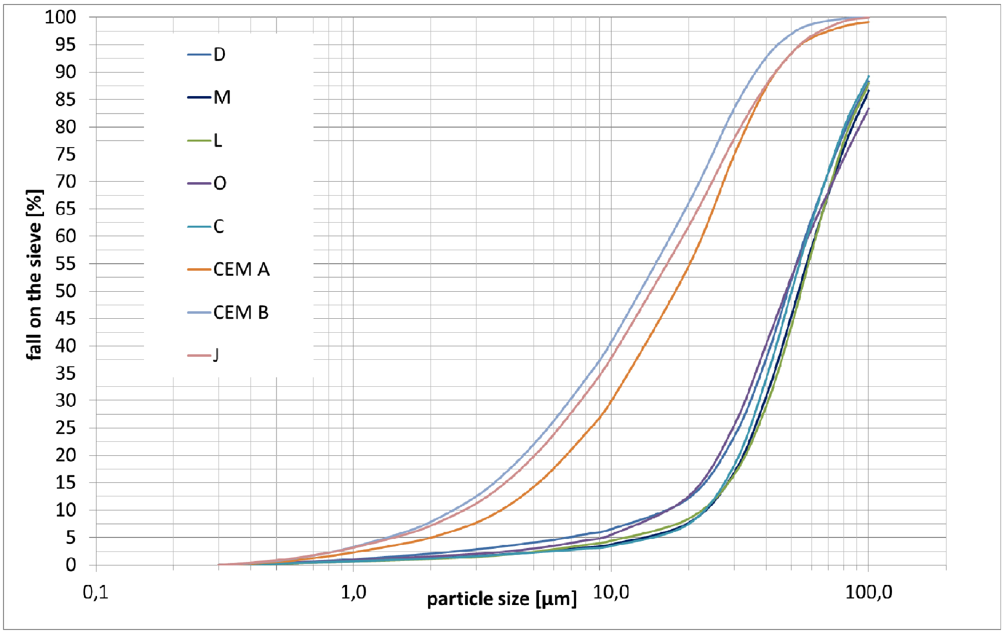

Fig. 2. Aggregate grading curve of fly ashes and cement from the laser granulometer

Fig. 3, shows that the ash J is the finest, the coarsest ash is fly ash L and O has the most spherical particles. Fly ash D is the finest among domestic ashes, which is evident from Fig. 3.

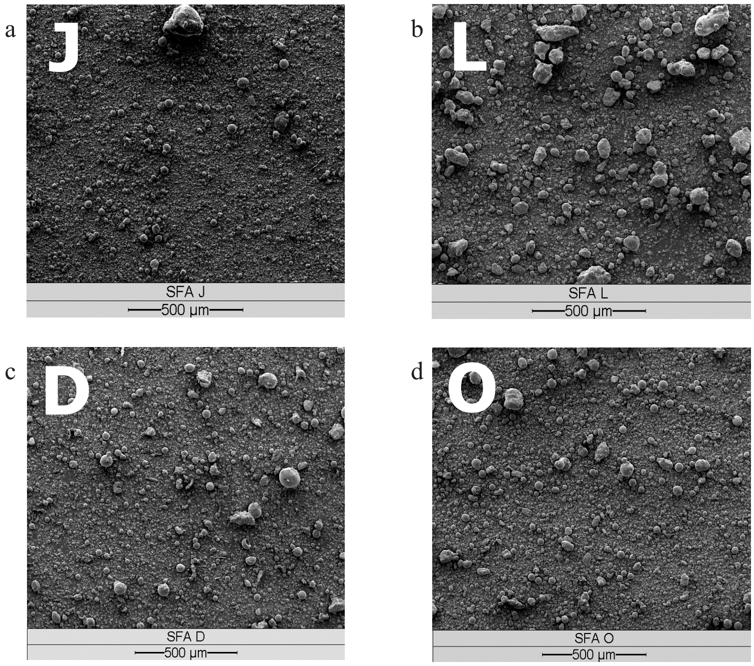

Fig. 3. Pictures from the electron microscope, magnification 50 times, a – fly ash JAR, b – fly ash Ledvice, c – fly ash Detmarovice, d – fly ash Opatovice

4. Conclusion

Based on the results tests of chemical - physical properties was selected Detmarovice ash (softness. quality. suitable grain), which was used for production of concrete. Currently, the research involved in the development of suitable chemical additives for concrete HVFAC. In further research is performed of validation formulations of concrete with Detmarovice ash and Ledvice ash with different substitution of cement by fly ash (10% to 70% by weight of cement). Tests have been focused mainly on the mechanical properties of the mixture after 28. 56 and 90 days for samples 40 x 40 x 160 mm. Also, larger samples are mixed as a cube with 150 mm. respectively beam 100 x 100 x 400 mm or 150 mm cylinder diameter and height of 300 mm to determine the compressive strength, tensile strength and flexural modulus of elasticity to the concretes designed HVFAC.

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